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WINTER-KILLING AND SMELTER-INJURY IN THE FORESTS OF MONTANA*

By George Grant Hedgcock

The great Washoe smelter at Anaconda, Montana, among the largest in the world, throws off annually, in spite of certain precautions taken to prevent it, a great volume of sulfur oxides and arsenic. There is little doubt, in view of the experiments made with sulfur dioxid, most of which have been made by European investigators, that this form of sulfur even when very dilutely diffused in air is injurious to plants. The fumes of arsenic take on a solid condition in open air and are probably not injurious to the foliage of forest trees. The effect of the accumulation of sulfuric acid and arsenic in the soil on the roots of plants is still somewhat uncertain, especially in small quantities. An excess, especially of the former, must undoubtedly interfere with the natural processes of decomposition and soil fertilization. The latter in large quantities can hardly fail to be poisonous.

During the winter of 1908–9 in some portions of the Northwest, more especially in Montana, many forest trees suffered from a peculiar form of injury which was apparently due to weather conditions the probable cause of which will be discussed in another paper. This injury was most severe in the following national forests: Absaroka, Beartooth, Bitterroot, Blackfeet, Deerlodge, Gallatin, Madison, and Jefferson. The injury was frequently quite severe. During the past three years, in all, about 40,000 acres of coniferous trees have died from its effects in Montana.

This form of winter injury has received the name locally of

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the "Red Belt" owing to the red appearance of the injured conifers, especially of the pines *en masse*, and the occurrence in most instances of the injured portion of the forest in narrow bands or strips of land, situated on the slopes of hills or mountains and running parallel to their bases, or to the valley floor below. The injury, judging from a consensus of observations by a number of observers, must have occurred in January, 1909, but was first noticed some time after it occurred, when the leaves began to redden and dry out. This injury took place at a time when the injury by smelter fumes in the region around Anaconda was a matter both of considerable discussion and litigation. This region reached by fumes from the Washoe smelter will be called the Smelter Zone in this paper. The matter of injury to the conifers in the Deerlodge National Forest became a matter of controversy, and the question naturally arose as to whether any of the "Red Belt" type of winter injury had occurred in the Smelter Zone.

The writer has spent a considerable portion of the past two summers making a study of the injury to trees by smelter fumes as compared with that of the winter of 1908–9 in order to separate the two forms of injury by differences apparent to the eye in the forest. It is found that while there are fine color distinctions in the two forms of injury that are easy to detect, when it comes to describing them in words, it is difficult to find terms to express these color distinctions exactly; on the other hand it is much easier to describe both their initial and final effects upon growth and behavior of the trees affected.

Smelter fumes and winter injury both redden the needles of pines in the more acute forms of each, but the smelter injury causes a brighter color and does not so often kill the whole leaf as in case of winter injury. In case of lodgepole pine and of Douglas fir trees, the Red Belt winter injury in the acute form killed not only the leaves but often the terminal buds and twigs, and the whole tree died the season following the injury. In the acute form of smelter or SO_2 injury the leaves die more gradually, and the terminal buds especially of the top shoots are the last to die. The death of such trees takes place slowly, from a more or less gradual defoliation often extending through several years;

and not from the effect of a direct and immediate injury, which killed the leaves by drying them out in a short space of time, completely defoliating and killingthe trees, as in the Red Belt.

The Red Belt injury occurred while there was a deep snow in most of the forests affected, and the younger parts of small pines and firs were injured only above the snow, the older parts covered with snow remaining green and healthy. On the other hand young trees suffering from acute smelter injury die in a reverse order, the lower limbs, and the older leaves dying first, the upper limbs and younger leaves last, the snow affording no protection in summer.

The less acute form of injury by smelter fumes usually known as chronic injury, causes a much slower defoliation of coniferous trees than the acute form. In lodgepole pines and firs, the leaves gradually lose their bright green color and become chlorotic, usually with a reddish tinge. All gradations between this appearance in typical chronic injury and the brightly reddened needles the acute form are found. In both forms the older needles are killed first, but in the chronic form, death takes place more slowly than in the acute.

In the less acute forms of Red Belt injury few terminal buds or twigs were hurt and only the leaves were affected. The leaves were reddened where the tips were killed, and in many instances the trees were nearly defoliated by the death of the needles in 1909. New green leaves, however, were put forth from the terminal buds of the less severely injured trees; some of these were chlorotic in appearance. Slightly injured trees lost only a portion of the foliage and recovered their growth at once.

A third form of smelter injury has been inaptly named invisible injury in Germany. This consists in a gradual and premature defoliation of the trees accompanied by a slight chlorosis and change of appearance in the leaves. This form checks the growth of the trees, and often at a later date assumes chronic form.

In all the forms of smelter injury in the smelter zone about Anaconda the general effect has been to form decreased annual wood rings year by year as the defoliation becomes more complete, until the width of a ring is often so slight that a powerful

lens is necessary to measure its diameter. In such extreme cases little or no autumn wood is produced in the rings. This tapering in growth in the wood rings is most pronounced in acute smelter injury, and the date of the first injury is often graphically shown by the first lessened annual ring, especially in young conifers.

On the other hand, coniferous trees injured in the Red Belt regions, entirely out of the Smelter Zone, do not as a rule show a gradual decrease in the annual increment for the past 5 to 10 years, as is shown by trees in the regions of acute and chronic injury in the Smelter Zone. In the most acute Red Belt injury, trees died suddenly after years of rapid and steady growth; in less acute forms where the trees recovered, there was little or no growth in 1909, followed by increasing growth or increment in the wood for 1910 and 1911.

The forested area in which the trees were killed by Red Belt injury was small when compared to the total area of the forests affected.

In Deerlodge National Forest, in the Smelter Zone, no greater percentage of the forest has suffered from Red Belt injury than has occurred in adjacent forests, in fact, according to the data collected by the writer, there is less of this injury.

The amount of damage in the same area in the Deerlodge National Forest due to wood-rotting fungi is no more than that in adjacent forests. Old and mature Douglas firs and pines are diseased occasionally with heart rots caused by *Polyporus Schweinitzii* and *Trametes pini*. On the other hand certain rusts, as *Peridermium elatinum*, *P. coloradense*, and species of *Phragmidium*, *Melampsora*, and *Roestelia* are almost entirely absent from the Smelter Zone around Anaconda, although often present in abundance in adjacent forests beyond this zone.

A great difference in the ability of conifers to withstand the effects of smelter fumes has been noted. The species in the Smelter Zone named in order of susceptibility to injury are as follows:

1. *Abies lasiocarpa* (Hook.) Nutt. (Alpine fir).
2. *Pseudotsuga taxifolia* (Lam.) Britt. (Douglas fir).
3. *Pinus contorta* Loud. (lodgepole pine).

4. *Picea Engelmanni* (Parry) Eng. (Engelmann's spruce).
5. *Pinus ponderosa* Laws. (western yellow pine).
6. *Pinus flexilis* James (limber pine).
7. *Juniperus scopulorum* Sarg. (Rocky Mountain juniper).
8. *Juniperus communis* L. (dwarf juniper).

The last three named species are quite resistant and in Deerlodge National Forest in the Smelter Zone show little or essentially no injury from smelter fumes.

The ability of trees to withstand the Red Belt form of injury is not in the same ratio as that of their resistance to smelter fumes. In order of the susceptibility to winter injury the species above named are as follows:

1. *Pinus ponderosa.*
2. *Pseudotsuga taxifolia.*
3. *Pinus contorta.*
4. *Pinus flexilis.*
5. *Picea Engelmanni.*
6. *Abies lasiocarpa.*
7. *Juniperus scopulorum.*
8. *Juniperus communis.*

All species showed some injury in the Red Belt winter injury of 1908–9. *Pinus flexilis*, *Juniperus scopulorum*, and *J. communis* exhibited, so plainly, forms of injury that the health of these species in the portions of the Smelter Zone where they are found is taken as proof that no winter injury has occurred in these regions during recent years.

The leaves of aspens (*Populus tremuloides* Michx.), alders (*Alnus tenuifolia* Nutt.), and of willows (*Salix* spp.) exhibit peculiar forms of leaf scorch, blackened, reddened, or discolored areas of parenchyma which are not found on leaves of the same species in other regions, in adjacent forests subjected to the Red Belt winter injury, but not to smelter fumes.

In much of the inner portion of the Smelter Zone adjacent to the smelter, few or no seed are borne by conifers, and little or no reproduction is taking place. The seedlings, apparently, are killed as soon as they appear above the ground. Not so in areas outside of the Smelter Zone, where only winter injury has

occurred. In such localities, reproduction is gradually beginning to take place.

In no other portion of Montana do we have a zone of injury comparable to that surrounding the Washoe smelter at Anaconda, where radiating from a central point, the injury decreases gradually outward in every direction from a common center. In this region where variation in the bands of injury occur, they can be shown to be due to the tendency of the clouds of smoke in damp weather either to settle in the valleys or to follow the easiest channels of surface configuration, here thrown against a slope, and there deflected away by striking a protected slope or valley.

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THE GENUS HAMELIA JACQ.

By N. L. Britton

Mr. H. F. Wernham has recently contributed to the Journal of Botany* a very useful account of *Hamelia*, a genus of Rubiaceae, comprising, according to his studies, twenty-eight species, all American, ranging from Florida and Mexico to Paraguay.

Of the twenty-eight species recognized, the following are described as new:

H. magniloba. Nicaragua.

H. grandiflora Spruce. Chimborazo.

* Jour. Bot. **49**: 206–216. Jl 1911. A supplementary note, loc. cit. 346. N 1911.